FURTHER CO_2 EMISSION MITIGATION BY MAKING OF SUPPLY WARM WATER TEMPERATURE LOWER IN THE HEAT PUMP & EVAPORATIVE HUMIDIFIER SYSTEM

Mitsuo Harada, Tokyo Electric Power Company, Tokyo, Japan
Toshihiko Kitamura, Tokyo Electric Power Company, Tokyo, Japan
Hideyuki Ito, Tokyo Electric Power Company, Tokyo Japan

Abstract: It is known that the heat pump & evaporative humidifier can mitigate CO_2 emission at heating and humidifying of air conditioning system, instead of steam heater and steam humidifier. And for the further CO_2 emission mitigation, it is known that to attempt making of the supply warm water temperature a low temperature than 45°C (113°F) so far, because it can increase the COP of the heat pump. But doing so, the power consumption of fan at the makeup air handling unit will increase, because of the number of rows of hot-water coils that exchange the heat of the warm water to air increases. So it is general to select the supply warm temperature 45°C (113°F) so far. In this paper it will be reported that the temperature of supply warm water of 30-35°C (86-95°F) is better for CO_2 emission mitigation at the total air conditioning system. And to select appropriate warm water temperature is a point of the COP improvement. As a result, the CO_2 emission mitigation with the heat pump is more possible.

Key Words: heat pump, evaporative humidifier, makeup air handling unit, COP

1 INTRODUCTION

Conventionally, direct combustion of fossil fuels or steam has been used as heat sources for heating and humidifying in makeup air-handling units in winter season. Using a “warm water heated by heat pump & evaporative humidifier” system as a heat source for heating and humidifying in these make up air-handling units would make it possible to vastly save energy conservation and CO_2 emission compared to the conventional system. It is because of high COP of heat pump and the energy-saving characteristics of evaporative humidifier. We used an “air source heat pump warm water heating & evaporative humidifier” in makeup air-handling unit and confirmed its energy-saving characteristics and CO_2 emission mitigation effect at IEA heat conference 2008[*2]. This time for the further CO_2 emission mitigation, we examined making of the supply warm water temperature low temperature than 45°C (113°F) so far. Photo 1 shows the typical type of air source heat pump chiller.

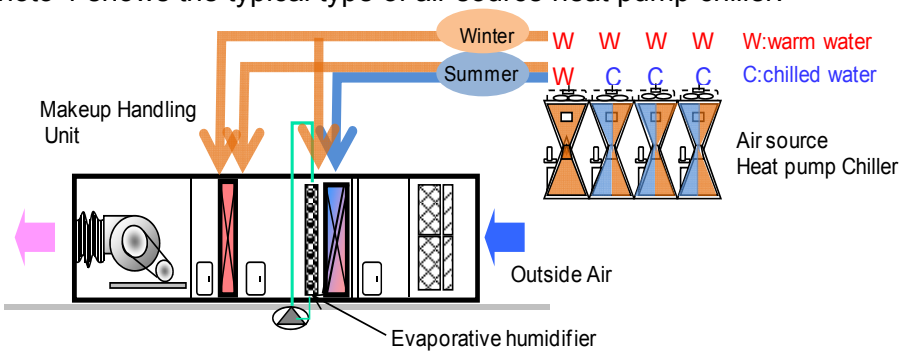


Photo 1: Air source heat pump chiller[*1] and Makeup air handling unit

2 SYSTEM CONFIGURATION

The upper row of Fig. 1 shows the equipment configuration of the makeup air-handling unit. Left side shows the conventional system, using the boiler, and right side shows the heat pump & evaporative humidifier system. The lower row of Fig. 1 shows movement of the state point on the psychrometric chart at heating and humidifying of both systems. On both figures, the movements of the state point are different, but the starting point and the goal point are the same. And the amount of the enthalpy necessary for the heating and humidifying are also equal. Table 1 indicates a necessary input and the pressure loss of the makeup air handling unit in both systems.

2.1 Conventional Heating & Humidifying System

At the conventional heating and humidifying system outside air is heated to around 23°C (73.4°F) by a steam heating coil. Then it is humidified using a steam atomizer to create the humidity conditions for room condition, and this air is ventilated to the room.

Air conditioning of Tokyo was used for the examination

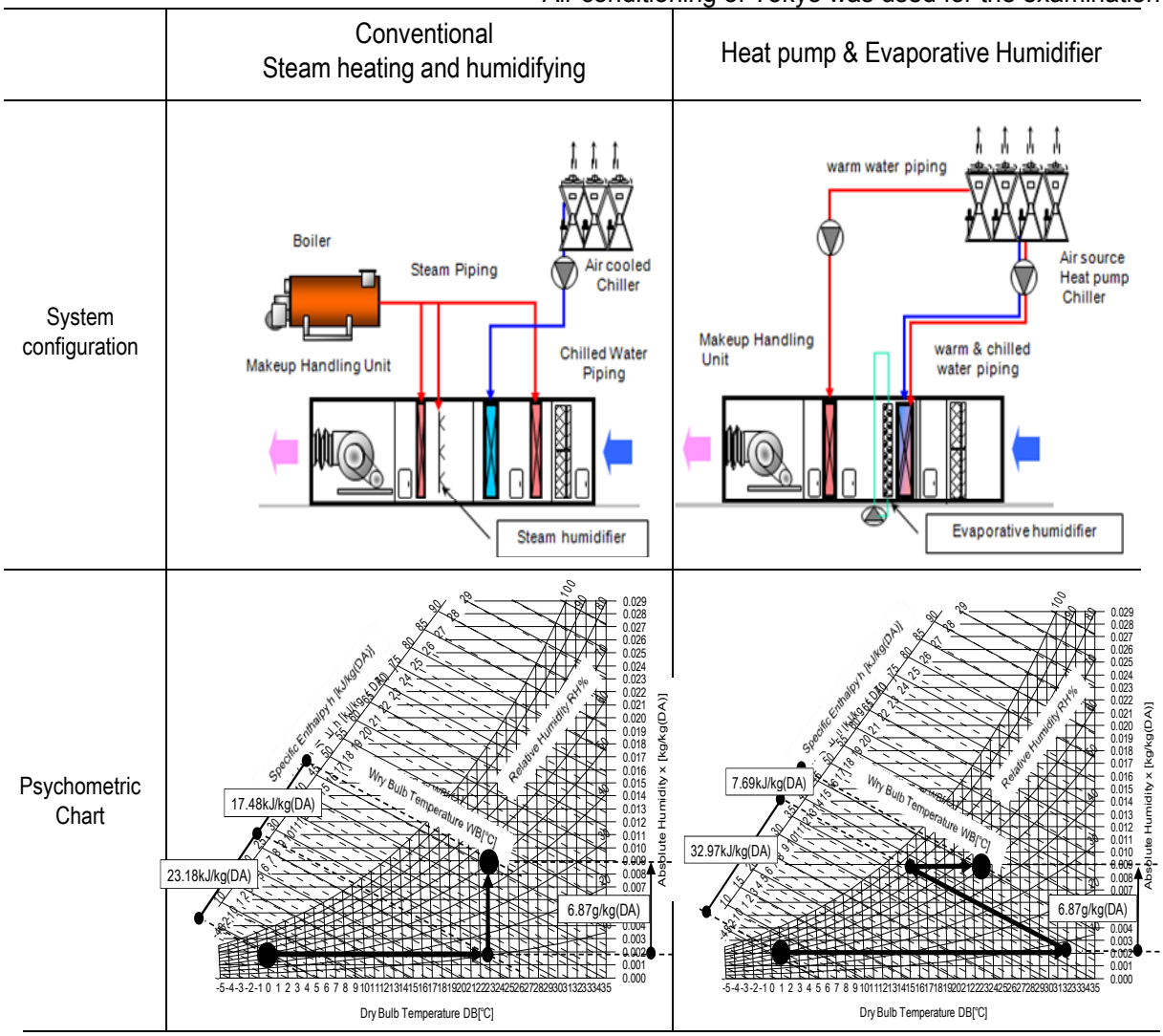
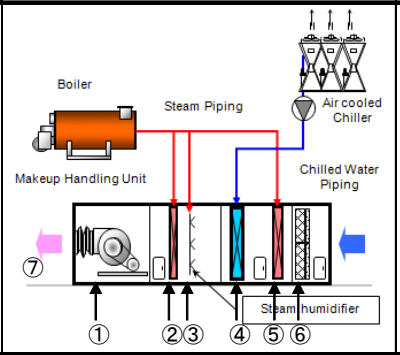
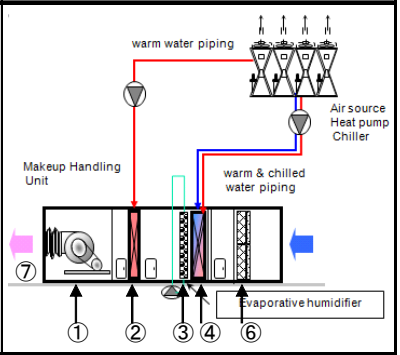


Figure 1: Equipment composition at makeup air handling system (Past and heat pump & evaporative humidifier)

2.2 Heat Pump & Evaporative Humidifier System

Lower right of Fig.1 shows the movements of state point on the psychrometric chart. There are two differences in this equipment configuration compared to the conventional system. The first is that a pump is required to convey the warm water generated by the heat pump chiller. And the second is that the makeup air handling unit requires additional fan power to compensate for the increased pressure loss inside the air handling unit due to the addition of the evaporative humidifier and the heating coil. The powers needed for each of these systems are shown in Table 1. The air outside is heated to 33°C (92.4°F) with the warm water coil that uses the warm water generated by the heat pump.

Table 1: Equipment configuration of makeup air handling system (Past and heat pump & evaporative humidifier)

		Steam Heating + Steam Humidifying		Heat Pump warm water heating + Evaporative Humidifying	
Equipment Configuration					
Makeup Handling Unit			Pa		Pa
Static Pressure	① Fan Air volume	20,000 m^3/h		20,000 m^3/h	
	② Reheater	54 kW steam volume = 86kg/h Coil Number = 2	5	54 kW warm temperature 45→38℃、 water volume 110ℓ/min Coil Number = 3	20
	③ Humidifier	Steam Jet 165kg/h	0	Evaporative 165kg/h	78
	④ Cooling coil	343 kW chilled water 7→14℃、 water volume 702ℓ/min coil number = 12	220	343 kW chilled water 7→14℃、 water volume 702ℓ/min coil number = 12	220
	⑤ Preheater	169 kW steam volume = 269kg/h coil number = 1	24	—	-
	⑥ Air filter	Medium Efficiency Pre Pressure up	98 49 98	Medium Efficiency Pre Pressure up	98 49 98
	⑦ Others	Casing loss Duct pressure drop	49 294	Casing loss Duct pressure drop	49 294
	Σ(① ~ ⑦)		837		906
Fan shaft power kW		7.8		8.4	

3 IMPROVEMENT OF HEAT PUMP COP BY TEMPERATURE CHANGE

Fig. 2 shows the COP change of heat pump that supplies warm water, in two states of the outside temperature degree. Usually the temperature of supply warm water is set at 45°C (113°F) for air handling unit in Japan. At that time, COP at the temperature of air 7°C (44.6°F) on the outside is 3.41. And, COP grows by the thing that the supply warm water temperature decreases. For instance, 3.14 rise up to 4.15 in COP when the supply warm water temperature can be adjusted from 45°C (113F) to 35°C. Another advantage is not that COP decreases because of making of the outside temperature degree a low temperature.

That is, if the supply warm water temperature is 35°C(95°F),the outside temperature degree becomes and COP becomes 3.51 even 0°C(32°F). And if the supply warm water temperature is 45°C (113°F), the outside temperature degree becomes 7°C (44.6°F) and COP becomes 3.41. The outside temperature degree is 0°C (32°F), 7°C (44.6°F), and COP of 0°C (32°F) is larger. Even if the outside temperature degree is low, high COP can be maintained.

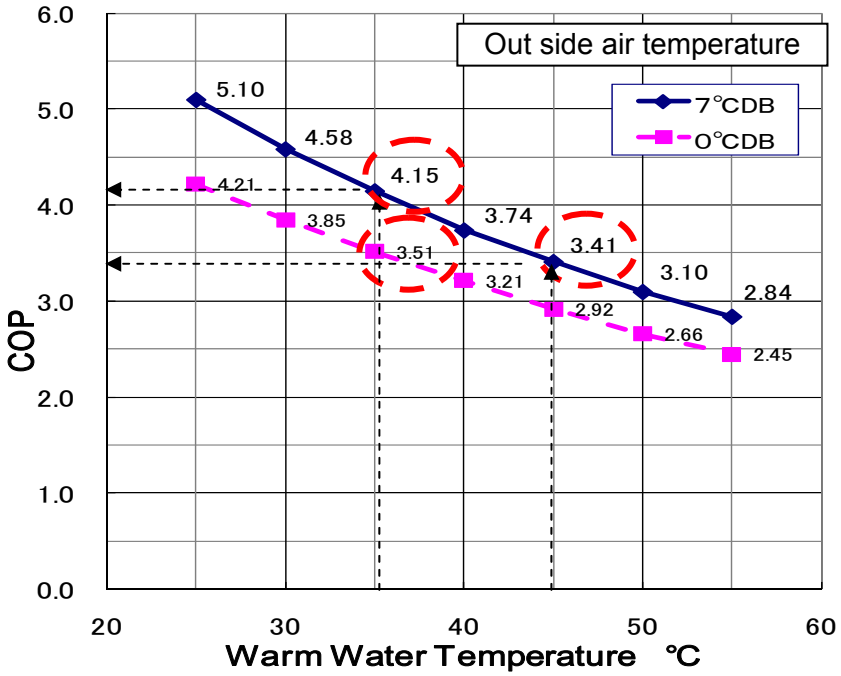


Figure 2: Changing of COP by change in supply warm water temperature of Heat Pump Chiller

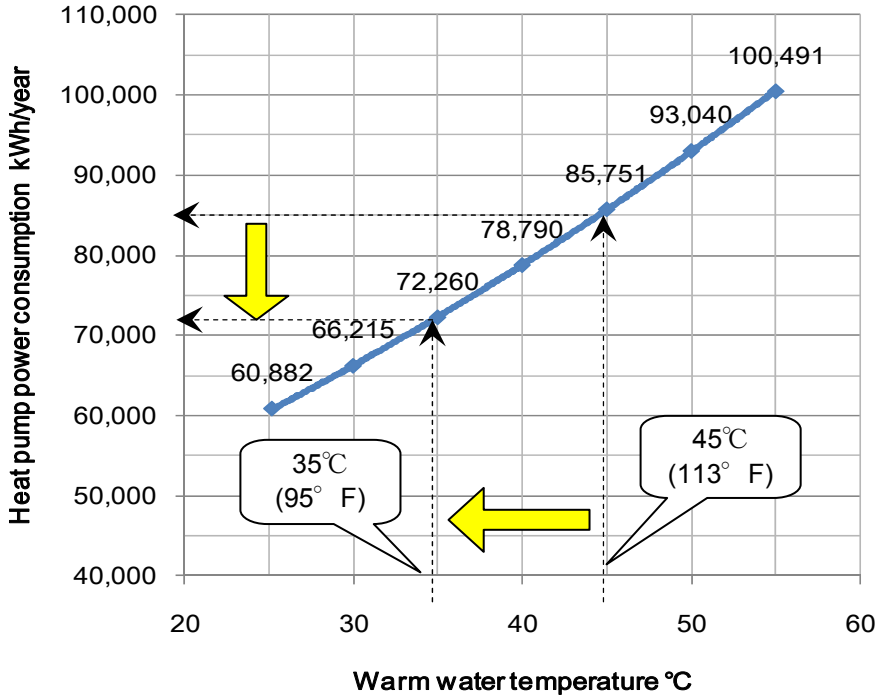


Figure 3: Change of Heat Pump Chiller Input Power by changing in Warm Water Temperature of Heat Pump Chiller (Air to Water) at outside air temperature 7℃ (44.6 °F)

Figure 3 shows the input change of the heat pump in year by the change in the supply warm water temperature in the heat pump. The input power consumption is 72,260 kWh during about one year, and, maybe, the heat pump becomes 16-% up performance therefore if transmutable to 35°C (95°F) the supply warm water.

4 FAN POWER CONSUMPTION OF AIR HANDLING UNIT

The number of rows of hot-water coils increases along with making of the supply warm water temperature a low temperature. Because of the Log-mean temperature difference becomes small. And ventilation resistance increases because of a warm water coil row number increase of the air handling unit, and the ventilation power increases. So fan power consumption of air handling unit rises. Fig. 4 shows the change of Fan input consumption by change of supply warm water temperature.

The expression of the log-mean temperature difference is shown (1).

$$\triangle t_m = \frac{\triangle t_1 - \triangle t_2}{\ell n\,(\triangle t_1 / \triangle t_2)} \qquad (1)$$

$\triangle t_m$: log-mean temperature difference

$\triangle t_1$: Temperatures fluctuate of both fluids at high temperature fluid entrance

$\triangle t_2$: Temperatures fluctuate of both fluids in high temperature fluid exit

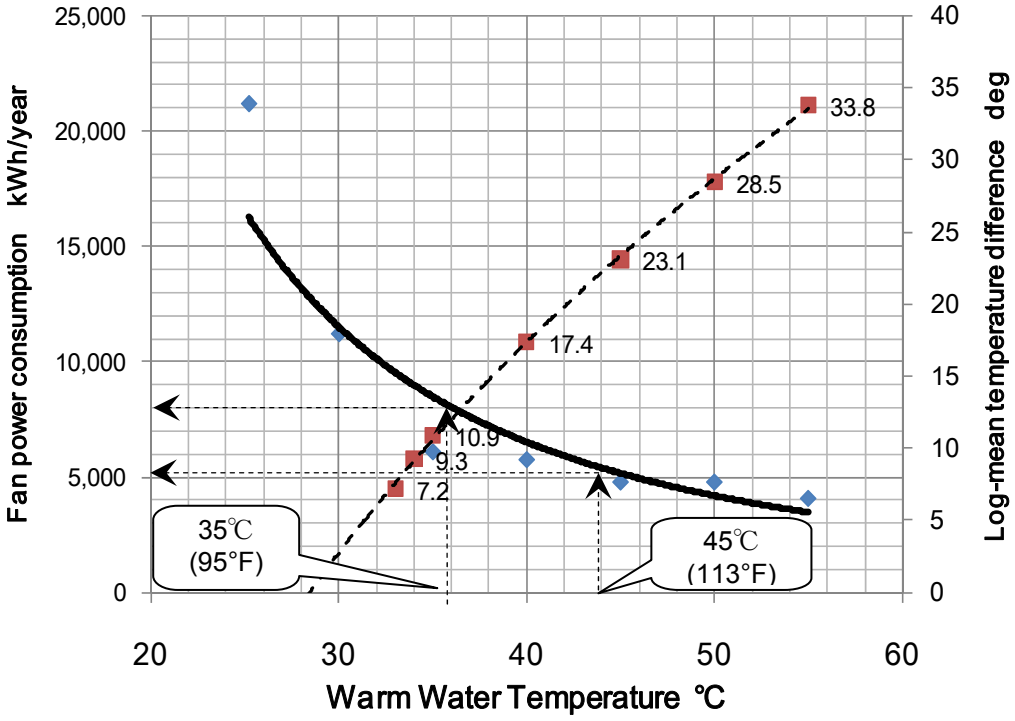


Figure 4: Change of Log-mean temperature difference and Fan Power consumption by changing in supply Warm Water Temperature degree

5 TOTAL INPUT POWER CONSUMPTION OF HEAT PUMP AND FAN

Fig. 5 shows the total input power consumption of Heat pump and fan by change of the supply warm water temperature. The total input power consumption becomes a small value by change the warm water temperature from 45°C (113°F) to 35°C (95°F). And it becomes a lowest value between 30°C (86°F) and 35°C (95°F). If the temperature of supply warm water could change from 45°C (113°F) to 35°C (95°F), the input power consumption becomes

down from 90530 kWh to 78,360 kWh, and the system becomes high efficiency 14% probably.

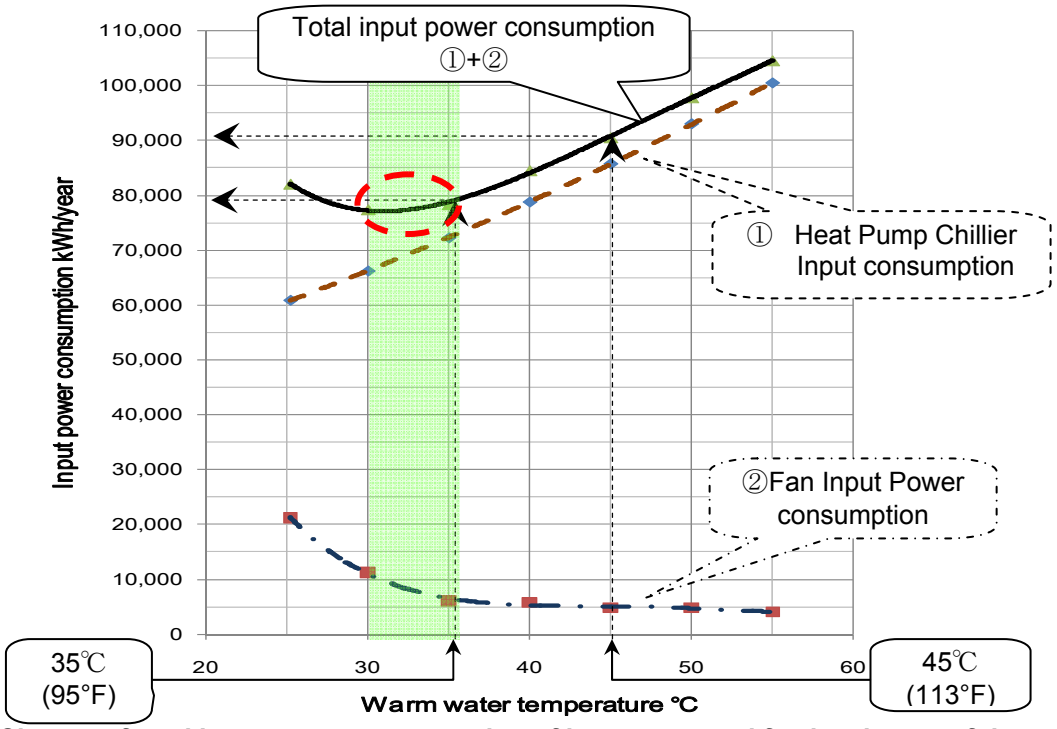


Figure 5: Change of total input power consumption of heat pump and fan by change of the Warm Water Temperature

6 EFFECT OF CO_2 EMISSION MITIGATION

Fig. 6 shows the comparison of the amounts of the CO_2 emission with the fossil fuel combustion and three kinds of heat pump warm water temperatures. It is understood to be able to reduce the amount of the CO_2 emission at air conditioning system with the heat pump & evaporative humidifier. And reducing the amount of the CO_2 exhaust by making the supply warm water temperature a low temperature in addition becomes possible.

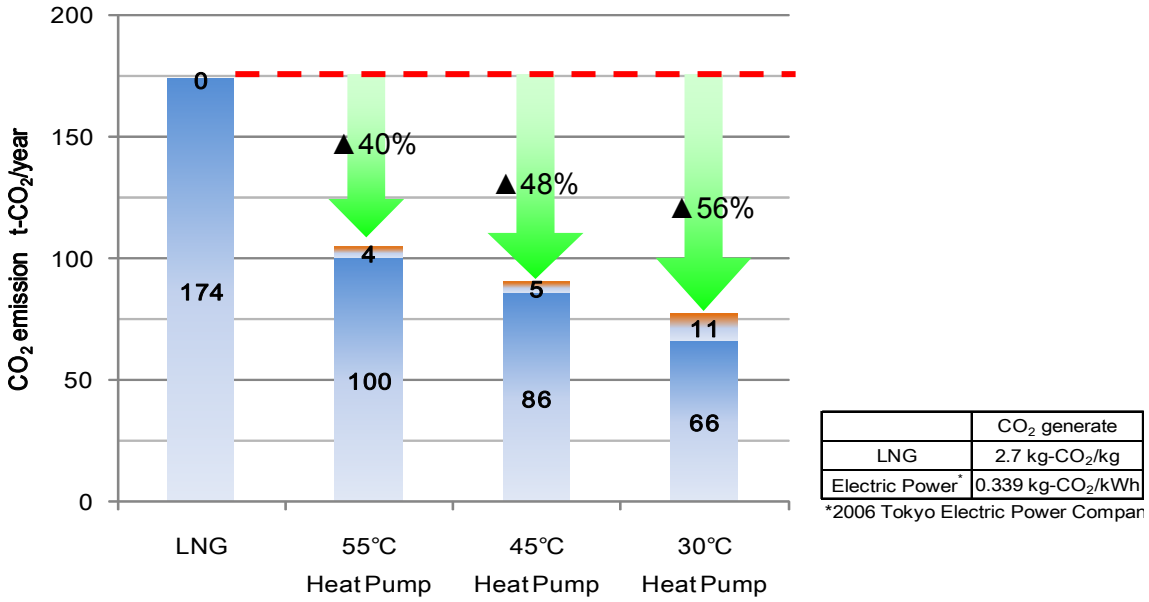


Figure 6: Effect of carbon emission mitigation by warm water temperature change at heat pump

6 CONCLUSION

It becomes possible the following from 45°C(113°F) past in temperature in the heat pump the generated supply warm water temperature by making it to the low temperature 30-35°C(86-95°F).

1) The heat pump power consumption can be reduced by about 20%.
2) Fan power consumption increases about 27%.
3) Total input power consumption of heat pump and fan load decrease about 15%.

To select appropriate warm water temperature is effective for heat pump COP improvement. As a result, CO_2 emission mitigation becomes more possible because of the combination of the heat pump and the evaporative humidifier at air conditioning system.

7 REFERENCES

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*2 : Mitsuo Harada, Toshihiro Nishikawa, 2008, CO_2 Mitigation using heat pump and evaporative humidifier in makeup air-handling unit, 9th IEA Heat pump conference